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CONSTRUCTION AND OPERATION OF A PORTABLE STILL TO PROCESS AGRICULTURAL CULLS FOR FUEL GRADE ETHANOL

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CONSTRUCTION AND OPERATION OF A PORTABLE STILL TO PROCESS AGRICULTURAL CULLS FOR FUEL GRADE ETHANOL

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June 1984

Prepared for

Montana Department of Natural Resources and Conservation
1520 East 6th Avenue, Helena, Montana 59620
Renewable Energy and Conservation Program
Grant Agreement Number RAE-439-811

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CERTIFICATION

I hereby certify that I am a registered professional engineer under the laws of the State of Montana and that this plan, specification or report was prepared by me or under my direct supervision and that I am competent to prepare this document.

Lawrence L. Stookey, P.E.

Reg. No. ENG07970E

Date 15 June 1984

EXECUTIVE SUMMARY

During this study, the operating characteristics of Eagle Still No. 0001 were observed. Beer of alcohol content between 0.9% and 3.4% was brewed from potatoes, corn and barley. This beer was distilled to produce fuel grade ethanol. The distillation product showed a maximum concentration of 88.4% ethanol by volume, or 176.9 proof. A maximum production rate of 21 U.S. gallons per hour was observed. Recommendations are made in this report which are intended to improve the continuous operation of the still. The mechanical operating procedure, an updated economic analysis, a description of Grant administration, future progress monitoring plans and as-built drawings are included as appendices.

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LIST OF ABBREVIATIONS

C	Celsius
F	Fahrenheit
FGE	fuel grade ethanol
g	gram
GPH	(U.S.) gallons per hour
GPM	(U.S.) gallons per minute
HP	horsepower
HR	hour
lb	pound
mg/L	milligrams per liter
mL	milliliter
MWU	modified Wolgemuth unit
PPH	pounds per hour
PSI	pounds per square inch
SOP	standard operating procedure
VAC	volts, alternating current
VDC	volts, direct current
w/v	weight per volume

INTRODUCTION AND OBJECTIVE

One of the results of world petroleum production shortfalls and the ensuing increase in cost of petroleum-based liquid fuels during the past decade is an increased interest in alternate energy sources. One of these sources is fuel grade ethanol (FGE) produced from agricultural products which contain fermentable carbohydrates.

This interest has manifested itself in Lake County, Montana, in the construction of a fractional distillation plant by Agrifuels of America, Inc. of Polson, Montana, under Grant Agreement No. 439-811 with the Montana Department of Natural Resources and Conservation (1). This Grant has as its goal the production of 16 U.S. gallons per hour (GPH) of FGE. Depending upon its intended use, FGE may range in concentration from 160 proof aqueous ethanol to 200 proof absolute ethanol (2). The purpose of this study was to gather and record performance data specified by the Department during the trials, and to summarize these data in a tabular form and submit the data to the Department as required under the Grant, and to determine the feasibility of using a portable still to process agricultural culls into FGE. Of necessity, a secondary purpose of this study was to brew beer from potatoes, corn and barley with the highest possible concentration of alcohol.

Because of budget limitations on the Grant, certain instrumentation relating to the measurement and control of flow, pressure, and temperature was not built into the still. This prohibited the collection of some desirable data and required the use of estimates. Data so obtained is noted in the body of the report.

PROCEDURE

Boiler Procedure

The operation of the boiler is standard and is described in detail in Appendix A. The only variable effect the boiler had in this study was the flow rate of steam drawn from it for brewing and distillation. This variable is addressed further in the subsection entitled "Distillation Procedure."

Potato Grinding Procedure

During the course of this study, several mechanical changes were made to the potato handling system. Most of these were either needed repairs or common-sense changes which would be obvious to those skilled in the art or operating the equipment. Two important changes, however, were:

1. The addition of 60% additional water flow at the top of the potato washer for a total of 8 HP centrifugal pump capacity.

2. The addition of a screen to the potato washer thrugh which recovered water drops into the washer reservoir. The intent of this screen was to remove small pieces of potato and potato sprouts which would otherwise clog the pump intake cage or the pumps themselves.

Liquefaction Procedure

Most of the alcohol produced by fermentation in the United States is made by wet grain milling. The literature regarding the fermentation of potato starch is much more scarce than that regarding the fermentation of cereal grains. Therefore, documented procedures for cereal grains have been used (3, 4, 5). It was found necessary to perform both laboratory-scale and full-scale fermentations in an attempt to quantify variables affecting the final ethanol concentration in our beer.

The variables associated with liquefaction are heat, mixing, and enzyme dosage. As discussed in Appendix A, heat is provided by direct injection of steam to a temperature of 90 degrees C. Full-scale batches ranging from 275 to 400 gallons of mash were used. The time for liquefaction ranged between 6 and 16 hours. The brand of alpha-amylase used was TAKATHERM by Miles Laboratories, Inc. An excess of this enzyme was used since our work was not intended to optimize enzyme feed rate. The completion of liquefaction was determined initially by negative starch-iodine raction on the full-scale batches and subsequently by reducing sugar measurements on the laboratory-scale batches. Cooling was accomplished by addition of water, by pumping into a cooler vessel, and simply by radiation of heat while the mash stood in the cooker.

Saccharification Procedure

At a temperature of 60 degrees C., glucoamylase (or amyloglucosidase) was added in excess. The brand used in this study was DIAZYME L-200 by Miles Laboratories, Inc. The enzyme was usually added in one dose but on some occasions two doses were used, one early in saccharification and another after it had proceeded for some time. The time allowed for this reaction was controlled between 1 and 16 hours, depending upon batch size and the observed rate of saccharification. The completion of saccharification was determined initially on full-scale batches by dilution and the use of glucose test paper, and subsequently on laboratory-scale batches by reducing sugar measurements. Cooling was performed both by tank recirculation and by radiation of heat as the mash stood in the saccharifier.

Fermentation Procedure

At a temperature of 33 degrees C., hydrated distillers yeast was added. The brand used in this study was BIOYEAST from Biocon U.S.A. The yeast was added at the rate of 2 lb per 1000 gallons of mash. No extra nutrients were used in the full-scale batches. Nutrient concentration was varied in the laboratory-scale batches. These nutrients contained mainly nitrogen and phosphorus compounds with amino acids and micronutrients such as iron, manganese, cobalt, zinc, and sulfur. They were added in the form of Dairy Phos

Mineral by Purina, and Biofeed from Biocon U.S.A.

In full-scale batches the temperature was controlled by injecting steam periodically. The laboratory-scale batches were incubated at a constant temperature in either an air or water bath incubator. The completion of fermentation was determined by the cessation of carbon dioxide generation, the reducing sugar concentration, and hydrometer measurements.

Distillation Procedure

The operating procedure is described in detail in Appendix A. Generally, the procedure to optimize the operation of the distillation column was one of feedback; gradually increasing the input of steam, beer and reflux to the column until the capacity of one of the output devices was reached, i.e. the spent beer or reflux pumps, or until column flooding commenced. The criteria for judging steam input were the spent beer temperature and the reflux rates, both distillate and inter-column, required to maintain column top temperatures at the desired levels. The criterion for adjusting beer input was the ability of the spent beer pump to keep up with spent beer and condensed steam production. The criteria for inter-column reflux were the temperature of the stripper top and the availability of condensate. The criterion for adjusting distillate reflux, of course, was distillate quality and availability.

RESULTS

Boiler Procedure

Variation in the rate of steam production does not affect the energy balance. Therefore no results of boiler operation are of great interest in this study. It should be noted that two related mechanical problems may occur during normal operation. First, difficulty arises when trying to preheat cold columns in which the residual condensate level is higher than the steam inlet. In this case the column cannot heat evenly and in fact steam bubbles collapse violently on contact with the cold condensate. This produces a characteristic mechanical shock and "banging" sound. The second problem occurs when the stripper column is flooded. Due to the nature of the column construction in this study, it may not be possible to tell from the sight glass if the stripper is flooding. If it is, and the flood level exceeds the level of the steam inlet, the same thing happens as described above. The spent beer temperature will be high (about 230 degrees F.), column temperatures may fall (depending upon steam flow), and instead of the "banging" sound, a regular and rapid oscillation of the column steam pressure gauge will be observed, with a range of 1 PSIG or so.

Potato Grinding Procedure

Potato grinding is a part of the entire brewing process. The results obtained by making the mechanical improvements noted in the previous section are those of reducing the operation from a 4 person to a 2 person job. The increased rate and stability of potato flow through the system provide a present grinding rate of 4 GPM of potato slurry. This amounts to an approximate 3-fold increase in productivity with a 2-fold decrease in manpower.

Liquefaction Procedure

It was found that although 275 gallon batches of mash heat to 90 degrees C. in about 6 hours, larger batches (up to 450 gallons) reach this optimum liquefaction temperature with great difficulty if at all, even in times of up to 16 hours. This happens for 3 reasons: The larger batch requires more heat (at a constant input rate), the larger batch provides greater surface area from which to radiate heat from the surface of the tank, and the steam injection pipes are subject to plugging by mash, often at unpredictable and inconvenient times. The increased holding time at 80 degrees C. usually provided apparently satisfactory liquefaction compared with holding at 90 degrees C. for 30 to 90 minutes, but such low temperatures do nothing to prevent contamination problems which will be discussed later.

Enzyme dosage was only a problem on one occasion in a full-scale batch, on which a starch test was positive after several hours of cooking. Additional enzyme plus another hour of mixing time were sufficient to complete liquefaction.

Mixing posed a special problem with large batches and long heating times for two reasons: First, the seals on the mixer shaft bearings leak and an objectionable amount of mash leaks onto the floor. Second, even when alpha-amylase is added to cold potato slurry, the mash gelatinizes and thickens before it reaches a high enough temperature for the enzyme to begin working. With larger batches, the time to pass through this temperature range (55 to 70 degrees C.) is long, and much mash (up to 25 to 30%) is thrown out of the cooking tank by the mixing paddles.

A corollary to the problem with heating rate is that of cooling rate. There exist in the mash thermophilic organisms capable of metabolizing and using up glucose. These organisms come from the soil, infected potatoes, and foreign matter in the feedstock. The temperatures obtainable during cooking with present equipment are not sufficient to kill these organisms. At the conclusion of liquefaction there exists some 3 to 5% glucose and maltose in the mash. If the mash is not cooled rapidly (within 1 to 2 hours), opportunity is given to these organisms to grow at the expense of final alcohol concentration in the beer. It was found that the cooling provided by 60 feet of 0.75 inch copper tubing and a cooling water flow of 4.5 gallons per minute was of insignificant help, due to lack of mixing in the cooling tank.

In addition, after a negative starch test was obtained, there always appeared to be a considerable amount of unliquefied feedstock in the form of chunks of potato which had survived the cooking and liquefaction process. This was also seen, but on a smaller scale, on the laboratory-scale batches even when minimum water was used and the potatoes were finely ground.

Saccharification Procedure

The amyloglucosidase used for saccharification is only capable of breaking the short chain dextrin starch molecules into maltose and glucose molecules. Any action upon amylose and amylopectin, the long chain and large branched starches) is minimal. Our results indicate that, as expected, the reducing sugar content approximately trebles during this stage, rising from the range of 3 to 4% to the range of 9 to 11% by weight. This has been so both in full-scale batches and laboratory scale experiments. The pH sensitivity of the particular branch of enzyme used has also been verified. As given in published literature, the activity is low at pH 5.5, but is at a maximum at pH 4.2. Although active over a wide temperature range, the enzyme was found to work better and more rapidly at temperatures between 50 and 60 degrees C., probably due both to chemical kinetics and the decreased physical viscosity of the mash which promotes easier mixing. The same comments on cooling found in the previous subsection also apply here.

Fermentation Procedure

We have found that the most important consideration in consistent fermentation is sanitation. It is necesasry that all tanks and piping be disinfected prior to use. Two batches of mash were lost due to infection. The first was distilled, but the second was discarded. Immediately thereafter, a sanitation program was established. It includes 3 major points:

1. Flushing of all piping with water immediately after use.

2. Disinfection of all piping and tanks with approximately 50 mg/L chlorine solution between batches.

3. Thorough washing of floor and lower walls with water, followed by sweeping with Lysol (TM) solution.

Lysol is not used in the tanks because of its residual activity, but chlorine solution may be used on the floors if necessary. After the sanitation program was placed in effect, no more infections were encountered. However, yeast dosage was always maintained at the relatively high level of 2 lb per 1000 gallons of mash in order for it to gain an immediate population advantage over any other organisms present.

The control of temperature was found to be important. Fermenting mash is not tolerant of large swings in temperature, and such tend to slow down the overall rate of fermentation. Since the present housing for fermentation is not heated, changes in ambient temperature will affect the temperature of the fermenting mash and the length of time required between steam injections. During severe fluctuations in weather, the temperature of some batches dropped unexpectedly to 20 degrees C., whereas in the most carefully controlled batches the temperature was maintained between 30 and 35 degrees C. Such control requires, in the absence of automatic temperature control instrumentation, on-site supervision every few hours, for a minimum of 5 to 6 temperature checks and steam applications during a fermentation.

The laboratory-scale batches were much easier to control. Fermentation generally consumed a shorter period of time and it was found that after cessation of carbon dioxide generation, the reducing sugar concentration was usually 1 to 5%

by weight. The problems encountered with the laboratory-scale batches were much the same as with the full-scale batches when using potatoes as a feedstock: It invariably appears that a good deal (presently unquantified) of the potato mash has not fermented, but remains as a heavy, gas-filled carbohydrate foam, floating on a suspension of already-fermented potato particles in beer. The maximum percentage alcohol in beer to date has been 1.42% for potato beer and 3.4% for barley beer, by volume. A summary of the results of all experiments appears in Table 1 and Table 2.

Distillation Procedure

The results of distillation are directly tied to the quality (per cent ethanol) and quantity of beer available. One problem with the distillation procedure is the small brewing capacity of 350 gallons per batch (average value). About 6 to 8 gallons of absolute ethanol need to be distributed on the columns of Eagle Still No. 0001 to assure dynamic equilibrium and to provide steady state operation. This quantity is just about equal to the volume of alcohol found in one batch of beer. The net result is that about the time the column has come to equilibrium, the beer supply is exhausted. A larger brewing capacity and higher ethanol concentration in the beer would help solve this problem.

Another difficulty has been the mechanical plugging of the beer line to the still by foreign objects. Each time the still must be shut down and cooled, some alcohol is lost upon startup before the spent beer comes up to an acceptable temperature in the bottom of the stripper.

Nevertheless, alcohol between 160 and 177 proof has regularly been produced at rates between 16 and 21 U.S. GPH from beer of less than 3.4% ethanol by volume. A summary of the results of all trials of the still funded by this Grant is found in Table 1. Results of laboratory experiments are found in Table 2. A copy of a typical log kept during distillation is found in Table 3.

CONCLUSIONS AND RECOMMENDATIONS

Boiler

An adequate energy balance and distribution between beer production and beer distillation is not possible without knowing the mass and temperature of steam used for each. With present instrumentation these are not available. The energy usage in this study has been calculated by conducting beer production and distillation operations separately, and measuring the fuel burned by the boiler. It is recommended that for future operations, a totalizing steam flow meter be provided for at least the steam flow to the still.

Potato Grinding

The entire beer production process is dependent upon maximum surface area in the substrate (or feedstock) for enzyme activity. It is recommended that a smaller screen be installed in the hammermill so that the ground potatoes will pass a 16 mesh screen.

Beer Production: Liquefaction, Saccharification, and Fermentation

The maximum alcohol concentration yet produced in beer during this study is 3.4% by volume. There is a decided difference between brewing beer from cereal grains and brewing beer from potatoes. This is likely due to differences between the cereal grain starch molecules and the potato starch molecules. These differences may include size, degree of branching, and physical encapsulation. Eagle Still No. 0001 is designed for an input of beer containing 10% alcohol by volume, as are most commercial distillation facilities.

It is recommended that further work be performed to increase the alcohol concentration in the beer. This work may include the following:

1. Use of different liquefaction enzymes.
2. Increased cooking capacity by higher steam pressure and temperature, more efficient injection, or insulated and jacketed tanks.
3. Changes in liquefaction procedure to better degrade the potato starch molecule.
4. The installation of a heat exchanger to rapidly cool liquefied or saccharified mash.

It is concluded that with the starch content of the potato feedstock availabale, beer with a minimum ethanol concentration of 8% by volume should be possible, given the proper refinements in technology.

Distillation

In order to conduct and document an adequate mass balance or energy balance on the distillation process, it is necessary to know (as well as the steam flow and temperature previously discussed), flow rates, temperatures, and compositions of the beer, spent beer, refluxes and distillate. This is not possible with existing instrumentation. Estimates of such data have been made where possible and are incorporated into Table 1 and the balances given on the working drawings.

In addition to the measuring devices mentioned above, it is recommended that the following mechanical modifications be made to the still:

1. A screening device should be added to the beer line to the still to prevent passage of foreign objects. This screen should contain 2 isolatable channels to allow continuity of flow while one channel is being cleaned.

2. The beer line past the screening device should be plumbed in 2 inch black iron pipe to resist plugging by beer containing dense, angular particles of cereal grain.

3. The stripper and rectifier sight glasses and associated valves should be changed to 1 inch diameter to prevent plugging by beer bottoms.

4. The construction of the bottom plate in the stripper should be changed to allow the sight glass to accurately reflect the liquid level in the stripper. At present it is subject to flow in the annular ring of fluid surrounding the bottom plate.

5. After beer of sufficient alcohol concentration is produced (8 to 10 per cent)

and distilled, the capacity of the spent beer pump should be reviewed to determine its adequacy. At present it appears to be the limiting factor in alcohol distillation.

6. Brewing capacity should be increased so that it is commensurate with distillation capacity.

It is concluded that, despite these recommendations, Eagle Still No. 0001 has produced fuel grade ethanol at rates exceeding 16 U.S. GPH Given sufficient beer with an ethanol concentration equal to that for which the still was designed (10 per cent), it should be capable of producing 190 proof aqueous ethanol at the same flow rates.

Batch No.	Feedstock	EtOH in Beer, %	Maximum Proof	Maximum Flow, GPH	Recovery, gal/Ton
840321	potatoes	0.28*	154.0	15	0.8
840322	potatoes	NA	INFECTED BATCH **		
840330	potatoes	1.21*	165.3	16	2.9
840331	potatoes	1.42*	173.8	16	3.4
840405	potatoes	0.91*	176.9	17	1.9
840416	potatoes	1.38*	WASTED BATCH ***		
840507	barley	3.40*	162.9	21	20.5

* = estimated value

** = This batch was brewed in a fertilizer vat which had not been disinfected. It exhibited a high foaming action typical of bacterial infection.

*** = This batch was determined to have an ethanol concentration of 0.90% after cessation of CO2 generation. It was decided not to expend the manpower or fuel to distill the batch. A sample taken at 66 hours of fermentation was analyzed at 96 hours and an ethanol concentration of 1.34% was found at that time.

TABLE 1. SUMMARY OF FULL-SCALE BATCH RESULTS

Experiment No.	Feedstock	Variable	Recovery, Gal/Ton	Recovery, % of theory
1	potatoes	QUALITATIVE ONLY*		
2	wheat flour	QUALITATIVE ONLY*		
3	potatoes	QUALITATIVE ONLY*		
4	potatoes	added water	6.72	24.9
5	potatoes	liquefaction time	9.31	34.5
6	potatoes	pre-cooking	6.24	23.1
7	potatoes	EXPERIMENT DISCARDED**		
8	corn	control for comparison	69.6	88.6
9	potatoes	nutrient concentration	9.91	36.7

* = These experiments were run for the purpose of establishing proper equipment operation and feedstock preparation methods.

** = This experiment was performed with potatoes of high solids content and minimum water. The resulting mash was a thixotropic dough and would not ferment properly.

TABLE 2. SUMMARY OF LABORATORY RESULTS

Time	Comments
84/04/09	
1535	Steam head up. EtOH level=5.75 in. Fuel=14.5 in KWR meter = 69028
1545	Steam = 1 1/4 turns. Beer in from red tank.
1552	Steam = 1. Increase beer.
1604	Steam = 1 1/8.
1605	Unplug beer line.
1606	Steam = 1 1/4
1626	Unplug beer line
1627	Increase distillate reflux.
1629	Unplug beer line.
1631	Unplug beer line.
1634	Shut down to check beer line.
1645	Steam = 1 1/8. Pumps on.
1657	Shut down to inspect. Wood in neck down.
1716	Steam = 1 1/8
1723	Reflux tank proof = 138.7
1732	Rectifier = 185 F. Stripper = 210 F. Beer = 105 F.
1745	R.T. = 156.0 proof.
1748	Increase reflux.
1800	R.T. = 166.0 proof. Beer line plugged.
1900	Steam = 1 1/8
1905	Shut down to find wood and bark in elbow.
1941	Steam = 1 1/8
1945	Pumps on, temps coming up.
1953	Steam = 1 1/4. Temps not high enough.
2011	Steam = 1 3/8
2025	R.T. = 169.9 proof. 2 gallons to storage.
2030	R.T. = 153.4 proof.
2033	Unplug beer line
2053	Steam = 1 1/4
2055	Pumps on.
2058	Steam = 1 3/8
2123	R.T. proof = 165.6.
2210	Steam = 1 3/8
2226	Steady and balanced at equilibrium.
2236	R.T. = 167.5 proof.
2244	Steam = 1 3/8
2322	R.T. = 176.9 proof.

--- Log continues to 0025 on 84/04/10 according to SOP.

TABLE 3. EXAMPLE OF DISTILLATION LOG.

APPENDIX A

MECHANICAL OPERATING PROCEDURE

Boiler Operation

The boiler is a York-Shipley model SPHV-50-2 fired with No. 2 fuel oil and rated at 1725 pounds per hour (PPH) of saturated steam at 150 PSI. To start from a cold condition, make certain that an adequate supply of water is available to the boiler, either through an elevated storage tank or through sufficient supply line pressure. If the boiler water supply line will also provide process water, then ensure that all process uses are isolated from the boiler by a pressure valve which gives the boiler priority. The boiler requires a minimum of 15 PSI and a pressure valve setting of 20 PSI will adequately protect the boiler from low water pressure. Ensure that there is a sufficient supply of No. 2 fuel oil available for the proposed period of use at a firing rate of 15.5 gallons per hour (GPH). Plug the boiler electrical power cord into a supply of 240 VAC, single phase. If insufficient water is present in the boiler, a solenoid valve in the feed water supply line will automatically open, allowing the boiler to take on water. After this, the boiler should fire. If however, the left McDonnell Miller valve has been blown down with the power on, it may be necessary to reset the internal switch by pressing in on and then releasing the metal push rod extending out of the valve. Also, if the photocell circuit commonly known as a "Fire-eye" has been tripped by low fuel or a flameout, it may be necessasry to reset it by pressing and releasing the red reset button. If voltage and water level are correct, both switches have been reset, and the boiler will still not fire from a cold condition, it may be necessary to seek assistance from a boiler repair service.

When the boiler fires successfully, it will run until steam pressure reaches the value set on the pressure limit switch. As steam is used, the boiler steam head pressure decreases, and the boiler will fire once more when the pressure has dropped to a value equal to the limit pressure less the differential pressure. Current operation calls for a limit of 20 PSI and a differential of 4 PSI, so that the boiler will fire when the steam pressure drops below 16 PSI and will cut out when the steam pressure climbs to 20 PSI.

After the boiler has been operated, it is necessasry to blow it down to remove sludge and sediment from the boiler and the McDonnell Miller valves. There are three blowdown valves, one on each of the McDonnell Miller valves and the main blowdown located at the rear of and under the boiler. Each of these must be opened until clear water flows from the discharge. In addition, the feed water line contains a sediment strainer which must be drained in the same manner. The time interval before blowdown is completely dependent upon the quality of the water and the percentage of time the boiler operates each day. Under current conditions, the boiler is blown down once approximately every five days. Regardless, if the boiler is to remain cold for a period of time after use, it whould be blown down while still warm.

Further maintenance of the boiler is beyond the scope of this section.

Potato Grinder Operation

The potato grinder is a 20 inch Montgomery Ward hammermill powered by a 2 cycle Wisconsin air-cooled engine with an approximate output of 16 HP at maximum throttle under load. Potatoes are fed from a metering bin by conveyors through a potato washing device and to the hammermill.

There are several pieces of equipment which must be started in order from the discharge (hammermill) end backward, and must be shut down from the back (metering bin) end forward. These are, in order of startup:

1. Hammermill
2. Conveyor feeding hammermill
3. Pump(s) feeding washer
4. Conveyor feeding washer
5. Metering bin conveyor

Make certain that power is available to all electrical equipment, that all gasoline engines are fueled, that water is flowing to the washer reservoir, and that an adequate supply of potatoes is in the metering bin (approximately 2 tons per 500 gallon cooking tank). This is a two person operation at present. Ensure that adequate manpower is present.

Start up the powered equipment in the order given above. Potatoes will flow from the metering bin into the washer. With sufficient water flow through the washer, the potatoes will cascade down the washer baffles. It is imperative that the pump intake hoses be positioned in a wire cage, and that a wire screen be placed between the bottom of the potato washer and the water reservoir to catch small pieces of potato and potato sprouts in the return water.

One operator's station is at the washer. It is necessary to periodically "steer" the potatoes down the washer with a paddle, push them through the funnel to the elevator, and to clean both the return water screen and the hose intake cage. Since the washer is also a rock remover, care must be taken not to lift the potatoes over the washer baffles, which action could free rocks which have been trapped.

The other operator's station is atop the hammermill, forcing potatoes into the mill when gravity will not feed them. This person must also act as a catcher for any rocks, pieces of wood or bark, or other foreign material which has found its way past the washer.

After the surge tank is at least one-half full of ground potatoes, the auger is started. Barring unforeseen stoppages or equipment failues, the hammermill will grind potatoes at a rate sufficient to keep the auger from running dry. Should it do so, it is stopped and restarted when the surge tank is again one-half full. Best operation of the auger is achieved when it is running partially full of ground potatoes, but not completely full.

The 500 gallon cooking tank should not be filled with more than 400 gallons of ground potatoes. At the conclusion of a grinding shift, the hammermill must be thoroughly washed down with a high pressure water stream and the surge tank must be rinsed out. Rocks must be hand-picked from the washer baffles, the return water screen must be cleaned, and the washer reservoir must be cleaned out and refilled with fresh water. The grinding floor must be cleared of all potatoes which have fallen from the conveyors and washer, and the floor should be washed down with high pressure water.

Cooking and Liquefaction

To the potato slurry, add an alpha-amylase such as TAKATHERM from Miles Laboratories, Inc. at a rate of 0.20% by weight based upon the dry solids content of the potato slurry. Assuming a solids concentration of 20%, this usually corresponds to approximately 600 mL per 400 gallons of potato slurry. Mix thoroughly and heat by steam injection. Optimum liquefaction occurs with this enzyme at 90 degrees C. in about one hour. If there is difficulty reaching this temperature, liquefaction may be performed at 80 degrees C. by extending the time. At the conclusion of liquefaction the reducing sugar concentration should be 3 to 5 per cent w/v, and a starch test should be negative.

Saccharification

After liquefaction is complete, the temperature should be lowered as quickly as possible to 60 degrees C. Unlike corn and cereal mashes, this should bedone without the addition of water to the mash. The pH must then be lowered to 4.0 - 4.5 with muriatic (hydrochloric) acid. This usually requires 2 - 3 liters of acid. depending upon the size of the batch and the solids content of the mash. Add an amyloglucosidase or glucoamyulase such as DIAZYME L-200 from Miles Laboratories. Inc. at the rate of 120 MWU per pound of starch. This usually corresponds to 500 mL of enzyme per 400 gallons of mash. At the completion of saccharification, the reducing sugar concentration should be 9 to 11 per cent w/v. and the mash should have the consistency of a thin gruel.

Fermentation

After saccharification is complete, the temperature is once again reduced as quickly as possible without the addition of water to 33 degrees C. While the mashis cooling, distillers yeast such as BIOYEAST from Biocon U.S.A.is slurried with water until a thin smooth paste is obtained (0.5 to 1 hour). It is added at the rate of 2 lb yeast per 1000 gallons of mash, or approximately 400 g per 400 gallons of mash. The yeast is mixed thoroughly into the mash and the temperature is carefully controlled at 31 to 35 degrees C. by steam injection and occasional mixing. The fermentation process is monitored by filtering mash and taking hydrometer readings periodically (at least every 12 hours). Reducing sugar concentration may also be measured. When the hydrometer reading is less than 1 degree Brix, or if it is between 2 and 5 degrees Brix and no change has occurred for several hours, fermentation is complete for the purpose of distillation. The completion of fermentation may also be seen as the cessation of carbon dioxide (CO2) generation. Fermentation usually ceases between 48 and 72 hours, depending upon the size of the batch, actual yeast dosage, temperature, and solids concentration.

Distillation

Startup

When a batch of beer is ready to distill, fire the boiler and allow it to produce a full head of steam (20 PSI). Connect power to the control panel and switch on the 12 VDC power supply, which will activate the temperature gauges. Ensure that all tank valves are closed except the outlet valve from the fermentation tank and the valve which isolates the lower valve bank from the beer line to the still. These two valves must be open.

Open the main steam valve on the boiler. Apply steam to the columns by opening the steam inlet valve approximately one turn. Monitor the temperature at the top of the 16 foot stripper column. When this temperature passes 200 degrees F., turn on the incoming beer pump. Current practice calls for beer to be pumped onto the seventh plate of the stripper, although there is provision to pump it onto the tenth plate instead. The discharge line valve from the beer pump should be open. The beer flow is controlled by pertially to completely closing the beer pump recirculation valve. A starting position is to have the handle of the valve at an angle of about 45 degrees to the line.

Monitor the sight glass at the bottom of the stripper. When it fills, turn on the spent beer pump and, like the incoming beer, control the flow by adjusting the recirculation valve. Watch the spent beer temperature. It should rise to over 210 degrees F. within 5 minutes. If it does not, slightly increase the steam flow or decrease the spent beer flow or both. This is a temporary measure until the temperature of the spent beer comes up, ensuring that little or no alcohol will be lost with the spent beer. As the columns reach equilibrium, it will likely be necessary to pump spent beer at maximum flow rate and to control the level in the stripper sight glass by adjusting the incoming beer flow. As the beer flow is increased or decreased, so must the steam flow.

Monitor the temperature at the top of the 20 foot rectifier. Shortly (15 to 30 minutes) after it reaches 170 degrees F., an alcohol-water solution will condense into the reflux tank. When the reflux tank is about half full, start the distillate reflux pump and begin refluxing back onto the top of the rectifier. The rate of this reflux controls the quality of the distillate product. Monitor the quality of the contents of the reflux tank on a regular basis, since the temperature of the top of the rectifier is not measurable with sufficient accuracy. The lower the proof, the higher one must make the reflux flow onto the top of the rectifier.

Monitor the sight glass at the bottom of the rectifier. As the liquid level rises, turn on the inter-column reflux pump and adjust the recirculation valve to control the reflux flow from the bottom of the rectifier to the top of the stripper. Increasing this flow rate will prevent overheating of the stripper. A normal position for the recirculation valve handle is about 30 degrees open (away from parallel with the line).

Steady State Operation

In practice, it takes a little over an hour and 6 to 10 gallons of absolute ethanol for the columns to come to equilibrium. At this point the column temperatures will be stable, the reflux tank contents will be at maximum concentration alcohol, and the sight glass levels will be constant. The beer flows, both in and spent, will be steady and the liquid level in the reflux tank will be steadily rising. Slowly open the line valve to alcohol storage just so that the level in the reflux tank remains constant. From this time on, only minor and slight adjustments to the controls need be made to "fine-tune" the system.

Shutdown

After all the available beer has been pumped to the still, the fermentation tank may be rinsed with water and the rinsings pumped into the still without interruption. Carefully monitor the quality of the contents of the reflux tank and when the proof begins to fall, cut off the beer flow to the still. Continue to apply steam to the columns until as much of the alcohol as possible has been distilled over, albeit at low proof. This conserves alcohol, and the contents of the reflux tank at shutdown will be used to start the next distillation shift. When the temperature of the top of the rectifier exceeds 210 degrees F., cut off the steam to the columns and when they are cool, pump out the condensate in the bottoms of both the rectifier and the stripper. Measure the volume and proof of the contents of the alcohol storage container, and determine the number of proof gallons distilled by comparison with the data taken after the last distillation shift. Shut down the boiler and rinse down the still and surrounding area with high pressure water.

APPENDIX B

ECONOMIC ANALYSIS

This section is a brief description of the revenues and expenses associated with the operation of a commercial ethanol production facility of the size produced with the funds from this Grant. For the purpose of comparison with other projects, we have also used the concept of cost-benefit ratio. In the context of this section, a cost may either be a direct expense such as labor, raw material, or energy, or it may be an indirect expense such as depreciation. Likewise, a benefit may either be cash revenue received as the result of a sale of product, or it may be a savings as a result of substituting a product or by-product for material which is usually purchased for cash. Examples of the latter are the use of ethanol as fuel in place of gasoline, and the feeding of distillers dried grains to livestock in place of grain.

Types of Costs

There are two types of costs, fixed costs and variable costs. Fixed costs are those which are constant in amount regardless of the level of production. Examples of fixed costs are principal and interest on debt retirement, sinking funds for bond retirement, lease payments, depreciation, and administrative costs such as management salaries and office expense. Variable costs are those which are dependent upon the level of production. Examples of variable costs are fuel, feedstock, product transportation, and production payroll, assuming that unneeded employees will be furloughed and called back as needed.

Choice Between Packaged and Field-erected Stills

This subsection is intended for those using this report who are faced with the decision whether to buy a packaged (turnkey) still or to construct their own. A saving of 8 to 10 per cent in cost is possible if the decision is made to have a still designed and constructed locally. However, this usually entails a substantial increase in lead time required between the commencement of the project and the first distillation of ethanol. Dollar figures relating to this choice are given in Table 4.

Operating Assumptions

Eagle Still No. 0001 is an experimental unit intended to demonstrate the practicality of on-site distillation of FGE. This economic analysis is based upon several assumptions in order to make the jump between experimental operation and commercial operation of the present unit. The first assumption is that the recommendations given in the body of this report are to be carried out, most especially with respect to increasing the brewing capacity. Next, the still will operate 2835 hours per year with a staff of three persons. The time consumed by the various operations is assumed to be as given in the section above entitled "Procedure." The feedstock will be potatoes. Current data indicates that potato growers in Lake county, Montana plant 2800 acres to potatoes with an average yield of 13.5 tons per acre. The cull rate is quite variable, but averages about 10 per cent of the crop (6). Present brewing technology will allow a yield of 12 gallons of ethanol per ton of potatoes, for a total production per year of 45,360 gallons of ethanol. As may be seen, this production rate is intended to exhaust the practical supply of culled potatoes in Lake county, Montana. Steam will be generated by burning No. 2 fuel oil. Energy consumption is assumed to be 33,000 BTU per gallon of ethanol produced. A value of 140,000 BTU per gallon is used for the heat content of No. 2 fuel oil. The current price for this fuel is $1.02 per gallon. Water consumption is assumed to be 16 gallons per gallon of ethanol produced, at a cost of $0.50 per 1000 gallons of water. Electrical power usage is estimated to be 24,000 KWH per year at a cost of $0.05 per KWH. The cost of upgrading and increasing the brewing capacity is estimated to be $50,000, and depreciation is computed on this figure on a straight line basis over five years. Of this amount, $23,000 is projected to be equity and the remainder to be debt. Interest is computed on the debt at the rate of 13 per cent per year. Federal and Montana state income taxes are computed at the regular corporate rates of 15 per cent and 6.75 per cent, respectively. A pro forma income statement for one year of commercial operation is shown in Table 5. This table uses the assumptions given above.

Field-erected Still

Contract Services	$7565
Equipment and Supplies	37679
Administration	8699
Additional Brewing Capacity	50000
Total Cost	$103943

Packaged Still

Mechanical Plant	$94170
Freight	10000
Plumbing	5200
Labor	500
Electrical	2500
Electrical Labor	1760
Total Cost	$114130

TABLE 4. COSTS OF STILL ALTERNATIVES

Revenues		
Sales	$74,844	
Federal Tax Incentive	18,144	
Total Revenue		92,988
Operating Expenses		
Utilities		
Fuel	10,906	
Electricity	1,200	
Water	363	
Telephone	1,200	
Feedstock	-0-	
Office Supplies	900	
Laboratory Supplies	1,200	
Depreciation	10,000	
Insurance	1,000	
Interest	3,500	
Travel	3,600	
Legal and Accounting	1,800	
Equipment Rental	600	
Salaries and Wages	43,000	
Employment Taxes		
FICA	2,946	
SUT	1,800	
Total Operating Expenses		$84,025
Net Income Before Taxes		8,963
Allowance for Income Taxes		1,949
Net Earnings		$7,014

TABLE 5. PRO FORMA INCOME STATEMENT FOR ONE YEAR

Market Analysis

This subsection is taken in part from a preliminary report prepared in September of 1983 and submitted to the Department of Natural Resources and Conservation as Milestone No. 4 of the Grant (7).

At the time of the completion of this Milestone, it appeared that there existed only one wholesaler of ethanol in western Montana, namely Missoula Cenex. This firm in turn sold ethanol to some six retail outlets which performed their own mixing and storage of gasohol, which is 90 per cent unleaded gasoline and 10 per cent anhydrous ethanol by volume. Volume data for October 1982 through August 1983 showed an average ethanol demand of 12,736 gallons per month, ranging between approximately 7,000 and 26,000 gallons per month.

To meet this demand, there is currently only one supplier providing ethanol to Missoula Cenex. This is Alcotec of White Sulphur Springs. This company is not able to meet the demand, with a capability of supplying only 6,000 to 7,000 gallons of ethanol every two weeks. This supply is transported to Missoula via a 9,000 gallon tank truck twice monthly.

Cenex management is not currently promoting mixed gasoline-alcohol products although they do offer at their own pumps both unleaded and regular leaded gasoline mixed with 10 per cent ethanol. The majority of customers purchasing these mixed fuels do so from desire for higher octane and benefit to their engines rather than from cost or energy considerations. This leads to the conclusion that price elasticity for gasohol may be fairly high. The location of distillation facilities near Missoula would reduce transportation expense and hence product cost. This cost appears to be a major factor in the present product loyalty. The other major factor is the lack of active marketing of mixed gasoline-alcohol fuels. A marketing and consumer education program such as was successfully carried out jointly during the 1970's by several midwestern states and petroleum companies would undoubtedly increase the demand for such fuels in western Montana and the surrounding area.

Financing

A problem for any business entity is to achieve the proper balance of debt and equity. Debt normally takes the form of long or short term notes with private persons or financial institutions. Debt in larger corporations may be offered as various types of bonds. Equity, on the other hand, is usually limited to common and preferred capital stock of either voting or non-voting class, and is obtained by offering part ownership of the assets of the company to investors in return for cash. The decision whether to organize as a sole proprietorship, partnership, or corporation is based strictly upon the number of organizers, their business and technical capabilities, and tax ramifications for them.

It is suggested that a business organization to operate an ethanol production facility such as Eagle Still No. 0001 might well be either a partnership or a regular corporation (as distinguished from subchapter S), with a debt ratio of 55 per cent (debt to assets). As may be seen from Table 5, a Return on Sales of 7.5 per cent is anticipated, with Times Interest Earned of 3.56. The relative high Return on Equity of 30.5 per cent is explained by the fact that a large portion of the physical plant was obtained under this Grant. A calculation of Internal Rate of Return shows that assuming the pro forma income statement to be reasonably correct, the business organization will have difficulty retiring the debt within the projected nine year life of the brewing equipment. This is so because of relatively high fixed costs. The solution to this problem may be to operate three shifts per day rather than one or two as planned, which will increase revenue much more than operating expenses, or to combine operations with an existing business organization and to share labor and utilities. An additional solution would be to increase the production capacity with another still and yet additional brewing capacity, since in this range of production level, i.e. 16 GPH, there is increasing economy of scale with larger facilities. The sizing of such increased production, however, is beyond the scope of this report.

APPENDIX C

GRANT ADMINISTRATION

Narrative Time Schedule

The long-range goals of this project were originally established to be the creation of jobs in an economically distressed area, and to make use of agricultural waste materials in the Mission valley of Montana. Since this area is a certified seed potato growing region, a large percentage of the potato crop is culled, and the culls must be disposed of at the growers' expense. In addition, the cherry growing industry of the area is periodically beset with large surplusses of unmarketable cherries due to late spring frost or rain just before harvest. In 1981, grants of $2500.00 each from the Montana Department of Natural Resources and Conservation and the Montana Department of Agriculture made possible the construction of a small pot still. Fuel grade ethanol produced from this still was used to operate a small farm tractor on the Leonard Hern farm south of Polson, Montana. Based upon this demonstration, the present Grant Agreement No. 439-811 was signed by the Montana Department of Natural Resources and Conservation on 25 June 1981 authorizing up to $50,000.00 for the construction of a pilot-scale continuous fractional distillation unit, portable enough to mount on a flatbad truck for transportation. During the first year of the Grant, negotiations were carried out for engineering design of the plant and for possible use of the plans and specifications for the Beard ethanol plant in Idaho Falls, Idaho. Trips were also made to Idaho Falls for the purpose of obtaining the transfer of the U.S.D.O.E. ethanol plant to the Mission valley. This plant was ultimately shipped instead to Tennessee. On 4 August 1982, the Grant Agreement was amended to provide more specific milestones for the now-necessary design and construction of the portable still. The next eight months were spent designing the plant and securing bids from contractors. This completed Milestone No. 1. The construction contract was awarded to Foothills Fabricating and Welding of Bigfork, Montana, and was executed between April and July 1983. This completed Milestone No. 2. This phase of the Grant was brought in with only a slight cost overrun. During July 1983 five trial batches of alcohol were produced from culled potatoes with a total output of 30 gallons of 36 proof ethanol. At this time the supply of culled potatoes was exhausted and the plant was mothballed for five months. During September 1983, an economic analysis and marketing plan was developed and submitted to the Department. This completed Milestone No. 4. In January 1984 the plant was disassembled, transported by flatbed truck to the Flathead Lumber Company in Polson, Montana, and reassembled. Between March and June 1984 seven batches of ethanol were produced from potatoes and barley which demonstrated the ability of the still to produce fuel grade ethanol in excess of 160 proof at rates in excess of 16 U.S. gallons per hour. This satisfied Milestone No. 3. Concurrently, laboratory experiments were conducted to improve the yield of alcohol. In June 1984 this final report was written and submitted to the Department, in completion of Milestone No. 5 of the Grant Agreement.

Summary of Expenditures

This subsection summarizes the expenditures for work performed under this Grant. The summary is given in terms of the budget categories set up for the Grant:

Contract Services	$7565.38
Equipment Purchased and Still Supplies	37679.37
Administration	8698.64
Salaries	-none-
Total Expenditures	$53943.39

The excess over the Grant amount of $50,000.00 represents cash donated by private sources toward the goals of the project.

Funds and In-kind Services From Other Sources

Due to the amount of public interest and support in the Mission valley for the goals of this Grant, cash, goods and services were donated by various persons and business establishments during the period of performance of the Grant. This subsection places a conservative fair market value on such donations and summarizes them in Table 6. It should be noted that many of the contractors and merchants, to whom direct payments were made as described in the previous subsection, provided their goods and services at less than market value. This should be recognized as additional support from other sources, although a fair market value cannot be assigned.

Donor	Item	Quantity	Rate	Amount
SFFG	Cash	$4,000		$4,000
FLC	Bldg. Rental	6 mo.	250	1,500
FLC	Eq. Rental	6 mo.	1000	6,000
FLC	Utilities	6 mo.	100	600
HF	Tractor Rental	200 hrs	50	10,000
HF	Bldg. Rental	2.5 yrs	9,000	22,500
Hern, H.	Labor	2080 hrs	5	10,400
Miles, D.	Labor	6240 hrs	5	22,500
Total Fair Market Value				$82,200

NOTES: FLC = Flathead Lumber Company

SFFG = San Francisco Feed and Grain

HF = Hern Farms

It must be understood that certain equipment may simply not be had on the rental market, and the fair market value has been estimated in accordance with modern business practices.

TABLE 6. MATCHING FUNDS AND IN-KIND SERVICES

APPENDIX D

Future Monitoring Plans

Grant Agreement No. 439-811 requires that the physical products of the Grant be made available for public inspection for a specified number of hours each year for five years after the completion of the project. In addition, Agrifuels of America, Inc. will submit a brief report each year. This report will summarize both technical and business achievements during the past year and will include the following:

1. Level of production of ethanol.

2. Employment opportunities created.

3. Changes in Business Plan.

4. Changes in energy efficiency and balance.

5. Cost of energy and feedstock as a fraction of market price.

6. Other extraordinary events during the year.

APPENDIX E

Working Drawings

This Appendix consists of six pages of drawings located in the pocket at the back of this report. They have been modified to reflect actual construction and operating experience.

LIST OF REFERENCES

1. Montana Department of Natural Resources and Conservation, Energy Division. Grant No. 439-811, as amended. Helena, Montana. 1981.

2. Borman, G.L., et al., "The Use of Alcohol in Farming Applications," under Contracts No. AC02-79CS-50025 and AC05-79CS-56051 to the U.S. Department of Energy, Office of Transportation Programs. Washington, D.C. 1980.

3. Dougherty, J. J., "Wort Production," from "The Practical Brewer", 2nd Edition, pp. 62-98. Master Brewers Association of the Americas. Madison, Wisconsin. 1977.

4. SERI/DOE, "Fuel From Farms," U.S.G.P.O. Stock No. 061-000-00372-0. Washington, D.C. February 1980.

5. McDowell, C. and Dawson, H., "Process Evaluation: Starch to Ethanol," Miles Laboratories, Inc. Elkhart, Indiana. 1982.

6. Bratton, E. County Extension Service, Lake County, Montana. Private communication. 5 July 1984.

7. Charles A. Brooke and Associates, "A Preliminary Analysis of the Ethanol Market in Western Montana." Private Communication. Missoula, Montana. September 1983.

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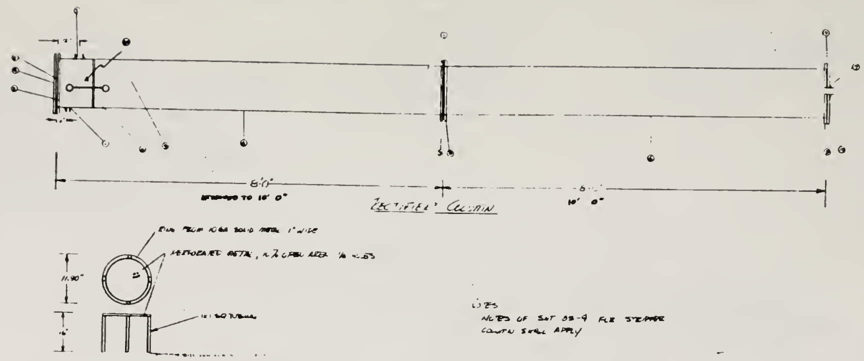
AIR FUELS OF AMERICA

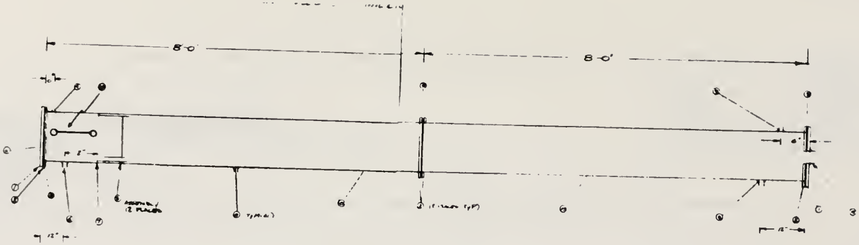

8'0"
EXTENDED TO 10' 0"
RECTIFIER COLUMN
8'0"
10' 0"
RIM FROM 10GA SOLID METAL 1" WIDE
PERFORATED METAL, [illegible] % OPEN AREA 1/8 HOLES
11.90"
16"
1x1 SQ TUBING

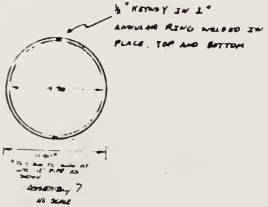
NOTES
NOTES OF SHT 83-9 FOR STRIPPER COLUMN SHALL APPLY

[illegible] , ½", WITH VALVES

METAL WELDED #25 PACKING TYPE [illegible] FROM NORTON COMPANY CALGARY, CANADA FILL ENTIRE COL). [illegible] BRAND USED, KOCH ENGR. CO., WICHITA, KS.
ASSEMBLY
THREDOLET 1½" x 3000 lb WELDED IN PLACE
SCHEDULE 40, 12" CS PIPE
FIBER GASKET
125# BLIND FLANGE 12" CS ASTM A105 (WELD TO MOUNTING BASE SEE DETAIL)
SLIP ON FLANGE 125# 12" CS ASTM A105
THREDOLET 2½" x 12 3000 lb WELDED IN PLACE ([illegible] VAPOR INLET)
THREDOLET 1x12 3000 lb WELDED IN PLACE (REFLUX OUTLET)

AS-BUILT REVISIONS	RECTIFIER COL
LAWRENCE L. [illegible] PE BOX 122 [illegible], MONTANA 15 JUNE 1984	BOB [illegible] CIVIL ENGINEER 217 MAIN ST [illegible] JANUARY [illegible]

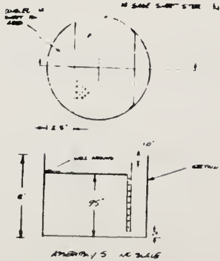



1/2" KEYWAY IN 2" ANNULAR RING WELDED IN PLACE, TOP AND BOTTOM
ASSEMBLY 7
NO SCALE

STRIPPER COLUMN

NOTES

1 BOLT ENDS ON FLANGES AS SHOWN FOR CLARITY, 10 USED.
2 FLANGES [illegible] 1/2" [illegible] 6 STUDS
3 [illegible] ALL BURRS AND SHARP EDGES
4 [illegible]
5 PAINT [illegible]
6 STACK ASSEMBLY 5 FROM BOTTOM, NEXT ASSEMBLY 5 TO [illegible] 7 W/ DOWNCOMER [illegible] ASSEMBLY [illegible] SHEET [illegible] ASSEMBLY
7 3 ASST MAY BE SUBSTITUTED FOR PIPE AND/OR MAY [illegible] AT THE [illegible] LIFE OF CS COMPONENTS [illegible] TO [illegible] OR LESS AT [illegible] PRODUCTION CAPACITY. CS USED.

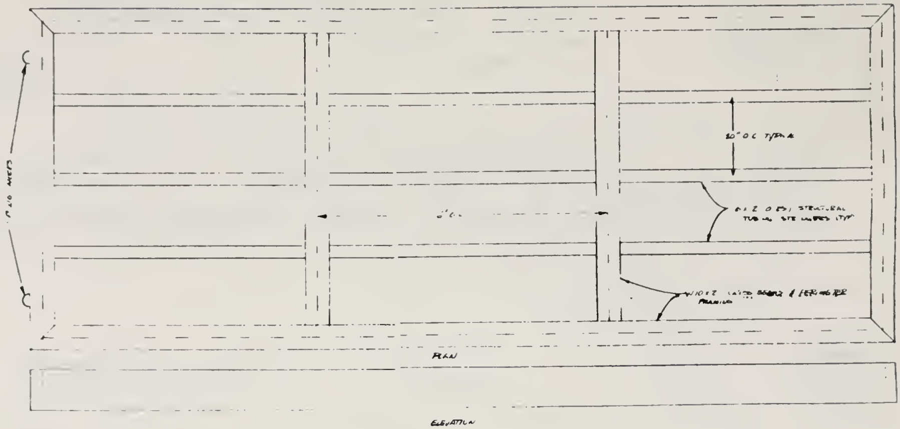

SAME SHEET STEEL 1/4" HOLES PUNCHED 10% OPEN AREA
2.5"
WELD AROUND
10"
6"
95°
SECTION CUT FROM SCH 40, 10" CS PIPE
ASSEMBLY 5
NO SCALE

● SIGHT GLASS, 1/2", WITH VALVES

SCHEDULE 40 12" CS PIPE
TOP OUTLET 2 1/2" [illegible] FLANGE WELDED IN PLACE
WELD THIS FLANGE TO BASE ASSEMBLY (SEE DETAIL FOLLOWING SHT)
THERMOWELL [illegible] WELDED IN PLACE 9" CC FROM BOTTOM
THREDOLET 1/2 3000 lb WELDED IN PLACE (REFLUX INLET)
THREDOLET 1 1/2 3000 lb WELDED IN PLACE ([illegible] INLET)
ASSEMBLY
THREDOLET 1 1/2 3000 lb WELDED IN PLACE (STEAM INLET)
ASSEMBLY
THREDOLET 1 1/2 3000 lb WELDED IN PLACE (SPENT BEER OUTLET)
REMOVABLE FIBER GASKET
45° SLIP ON FLANGE 12" CS WITH 8 HOLES
75° [illegible] FLANGE 12" CS [illegible]

AS-BUILT REVISIONS	STRIPPER C
LAWRENCE L. STOOKEY, PE BOX 122 RONAN, MONTANA 15 JUNE 1984	BOB FULTON CIVIL ENG 217 MAL KEVIN Ha JANUARY

Portable Installation Plant Mounting Deck

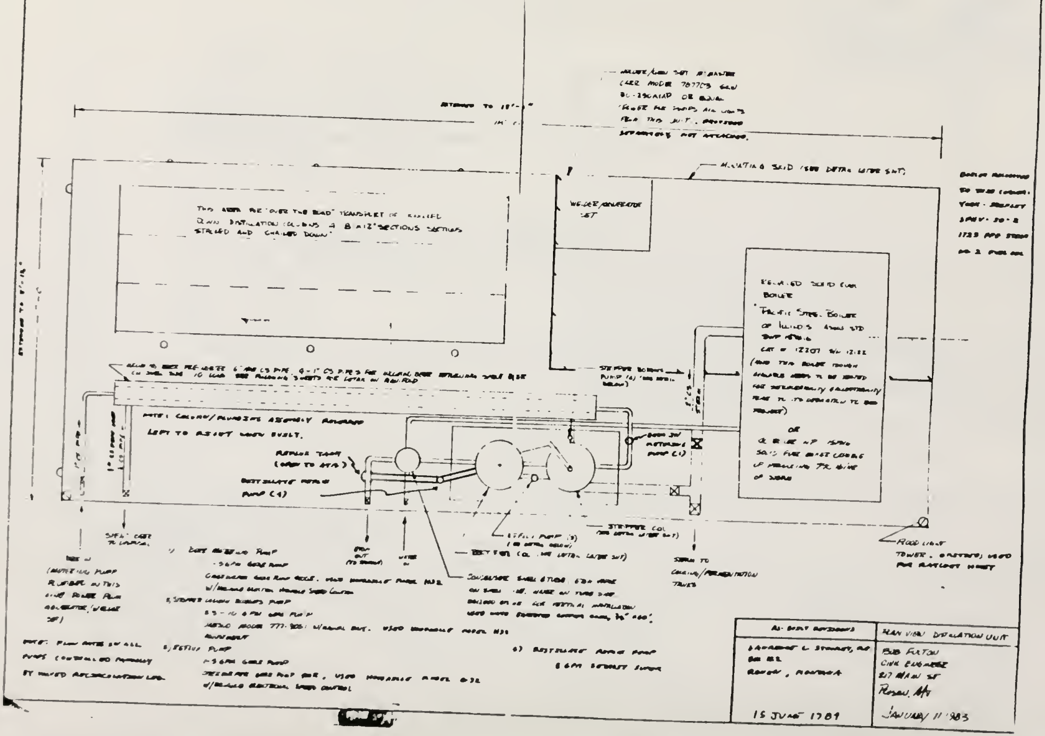

30" O.C. Typical
6 x 2 0.25 structural tubing [illegible] (typ)
W10 x 2 [illegible] beams & perimeter framing
8' O.C.
[illegible]
Plan
Elevation

Notes

1. All welds to be [illegible] w/[illegible] prior to fabrication
2. Steel - A36
3. Surface of deck to be [illegible] checker plate
4. [illegible] 2 head units 7x8' actual 8'-10" x 18'-3"

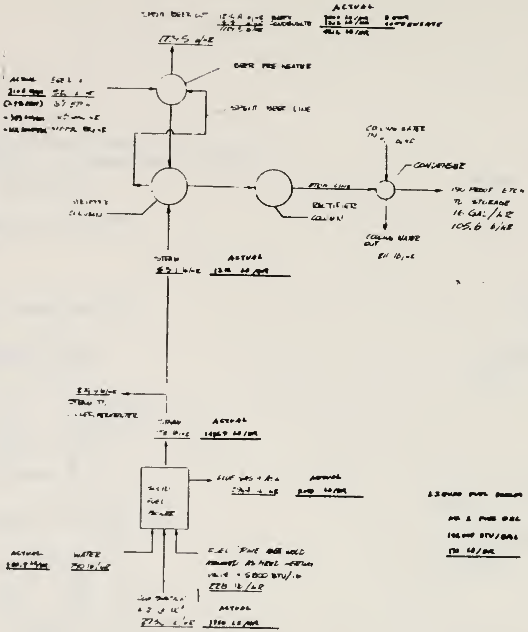
[illegible]	Plant Mounting Deck
[illegible] & [illegible] Rd Box 1[illegible] [illegible], Montana 15 June 1984	[illegible] 217 Main St Polson Montana January 11 1985

AGRI-FUELS PORTABLE DISTILLATION UNIT - PLAN VIEW


MOUNTING SKID (SEE DETAIL LATER SHT)
WELDER/GENERATOR SET
THIS AREA FOR "OVER THE ROAD" TRANSPORT OF ROLLED DOWN DISTILLATION COLUMNS 4 8 x 12" SECTIONS STACKED AND CHAINED DOWN
NOTE: COLUMN/PLUMBING ASSEMBLY ARRANGED LEFT TO ADJUST WHEN BUILT.
REFLUX TANK (OPEN TO ATM)
DISTILLATE RETURN PUMP (4)
STRIPPER BOTTOMS PUMP (2)
STRIPPER COL
RECTIFIER COL
REFLUX PUMP (3)
CONDENSER SHELL & TUBE
FLOOD LIGHT TOWER
STEAM TO COOKING/FERMENTATION TANKS
WATER IN
OUT
SKID CART
MASH IN
RECLAIMED SKID FLOW BOILER
PACIFIC STEEL BOILER OF ILLINOIS
CAT # 12207
OR
EXTEND TO 18'-0"
PLAN VIEW DISTILLATION UNIT
BOB FULTON
CIVIL ENGINEER
217 MAIN ST
ROSEAU, MN
JANUARY 11 1983
15 JUNE 1981

AGR. FUELS OF AMERICA
POLSON, MONTANA

MASS BALANCE



ENERGY BALANCE

	BTU/HR	ACTUAL
OUTPUT		
Ethanol	1.26 × 10^6	
Other Alcohols	0.05 × 10^6	
	1.31 × 10^6	
INPUT		
Cooker	0.256 × 10^6	[illegible] × 10^6
Stripper Column	0.384 × 10^6	[illegible] × 10^6
Rectifier Column	0.126 × 10^6	[illegible] × 10^6
Actual alcohol production	0.77 × 10^6	[illegible] × 10^6
20% system losses (assumed)	0.15 × 10^6	[illegible] × 10^6
	0.92 × 10^6	1.753 × 10^6

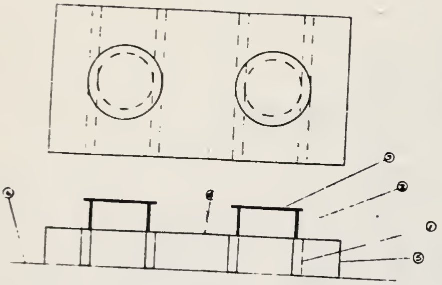
Assume 70% boiler efficiency

∴ Boiler Rating 1.32 × 10^6 BTU/HR
= 39 HP (boiler)

ACTUAL

2.50 × 10^6 BTU/HR
= 74 HP (boiler)

AS-BUILT REVISIONS	ENERGY/MASS BALANCE
Lawrence L. Stowers P.E. Box 182 [illegible], Montana	For Fulton [illegible] 217 Main St Polson Montana

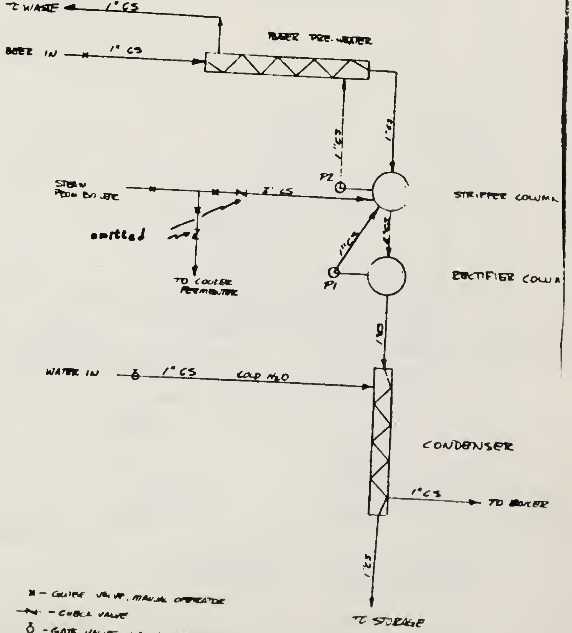


COLUMN MOUNTING PAD

NOTE
TO BE WELDED TO DECK

⑥ SURFACE OF MOUNTING DECK
⑤ 2x6 ANGLE IRON ON PERIMETER OF MOUNTING BASE
④ ¼" STEEL PLATE
③ .25" BLIND FLANGE (SEE COLUMN DETAILS)
② SCHEDULE 40 10" CS PIPE, WELDED TO ¼" PLATE ON BOTTOM AND ③ ON TOP
① 2x6 STRUCTURAL STEEL (A36) TUBING, WELDED TO DECK

PIPING DIAGRAM



✕ - GLOBE VALVE, MANUAL OPERATOR
-N- - CHECK VALVE
δ - GATE VALVE, MANUAL OPERATOR
P1 - REFLUX METERING PUMP
P2 - STRIPPER COLUMN BOTTOMS PUMP

20 copies of this public document were published at an estimated cost of $5.25 per copy, for a total cost of $105.00, which includes $105.00 for printing and $.00 for distribution.